US009048054B2

(12) **United States Patent**
Potratz

(10) **Patent No.: US 9,048,054 B2**
(45) **Date of Patent: Jun. 2, 2015**

(54) **CIRCUIT BREAKER WITH PLUG ON NEUTRAL CONNECTION LOCK-OUT MECHANISM**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 1220 days.

(21) Appl. No.: **12/956,736**

(22) Filed: **Nov. 30, 2010**

(65) **Prior Publication Data**

US 2012/0132506 A1 May 31, 2012

(51) **Int. Cl.**

H01H 9/28	(2006.01)
H01H 83/02	(2006.01)
H01H 9/20	(2006.01)
H01H 83/22	(2006.01)
H01H 83/20	(2006.01)

(52) **U.S. Cl.**

CPC ***H01H 83/02*** (2013.01); ***H01H 9/20*** (2013.01); ***H01H 83/223*** (2013.01); *H01H 2083/201* (2013.01); *H01H 2083/203* (2013.01)

(58) **Field of Classification Search**

CPC H01H 9/20; H01H 71/62; H01H 71/505; H01H 77/06; H01H 71/125; G01R 31/025; H02H 1/0015

USPC 200/43.11

See application file for complete search history.

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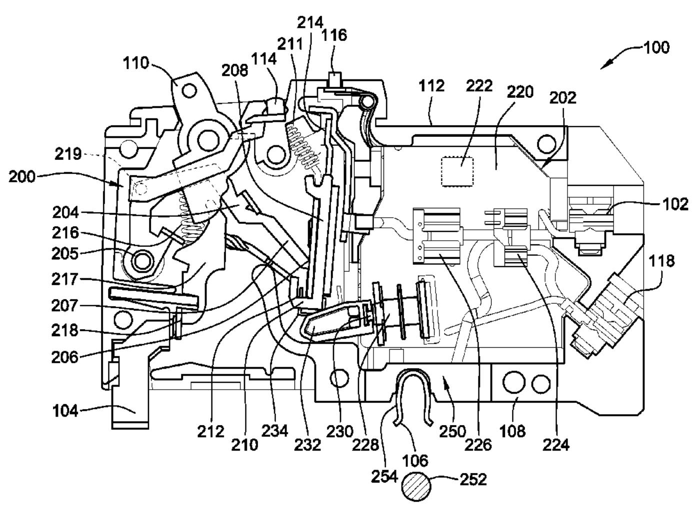
(57) **ABSTRACT**

A circuit breaker is disclosed that has a neutral lock-out mechanism that prevents electrical connection between a power source and a load when a neutral rail is disconnected from the circuit breaker. The circuit breaker has a line connector, a load connector and a plug-on neutral line connector. A trip mechanism has an on position allowing electrical connection between the line connector and the load connector. The trip mechanism has a tripped position interrupting electrical connection between the line connector and the load connector in response to detection of a fault condition such as a short circuit. The trip mechanism also has an off position which is required before resetting the trip mechanism to the on position. A trip link is coupled to the trip mechanism. The trip link has a first position that prevents the trip mechanism from being reset to the on position. The trip link has a second position allowing the trip mechanism to be reset to the on position. A neutral lock mechanism is coupled to the plug-on neutral line connector. The neutral lock mechanism has a tension spring that retains the trip link in the first position when the neutral rail is disconnected from the neutral line connector. When the neutral rail is inserted into the neutral line connector, the tension spring is compressed and the trip link may move to the second position allowing the circuit breaker to be reset.

16 Claims, 9 Drawing Sheets



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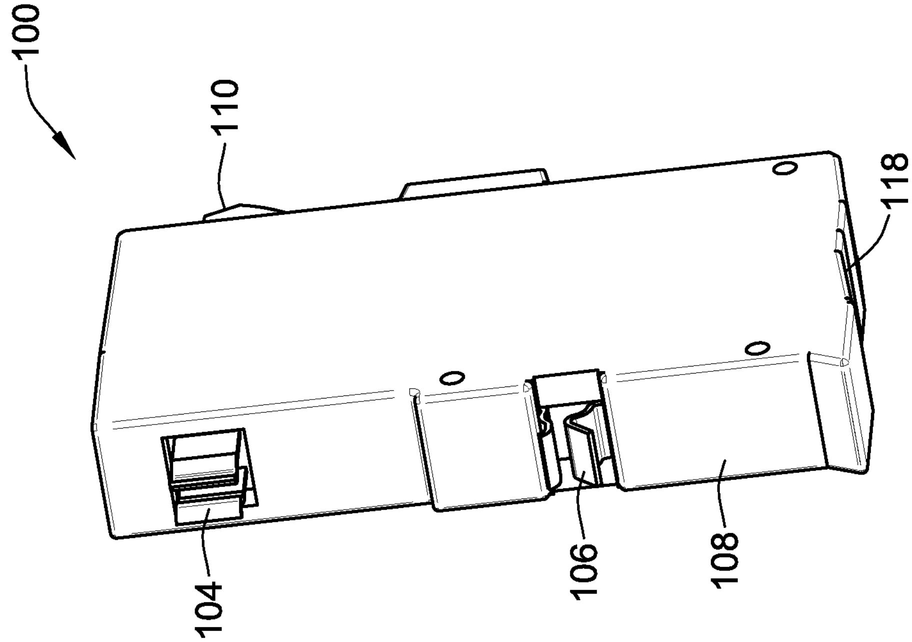

FIG. 1B

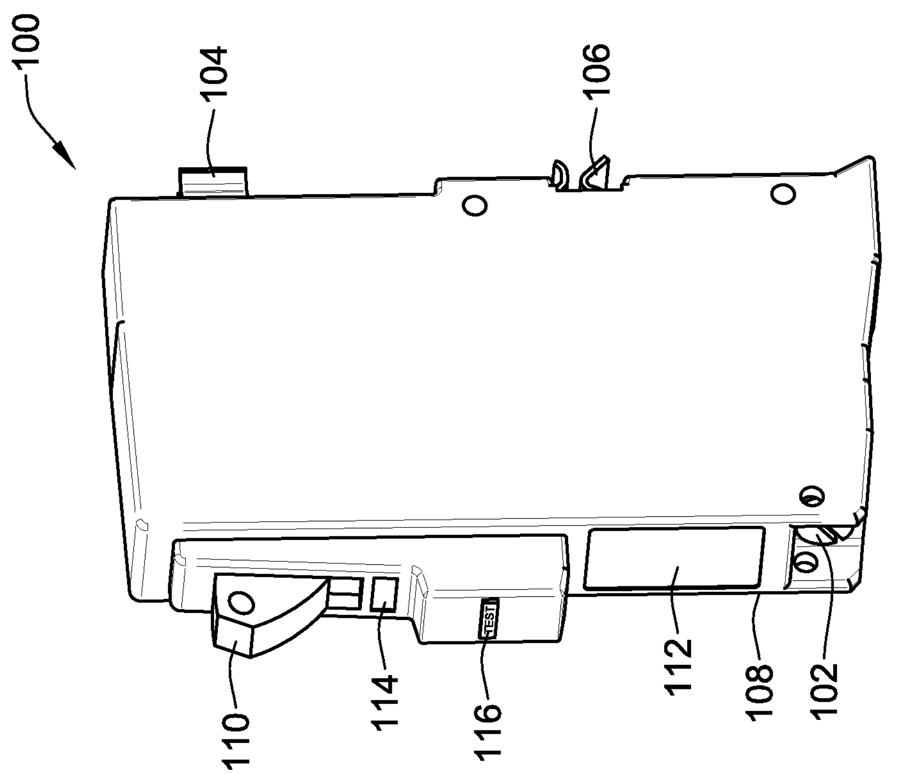

FIG. 1A

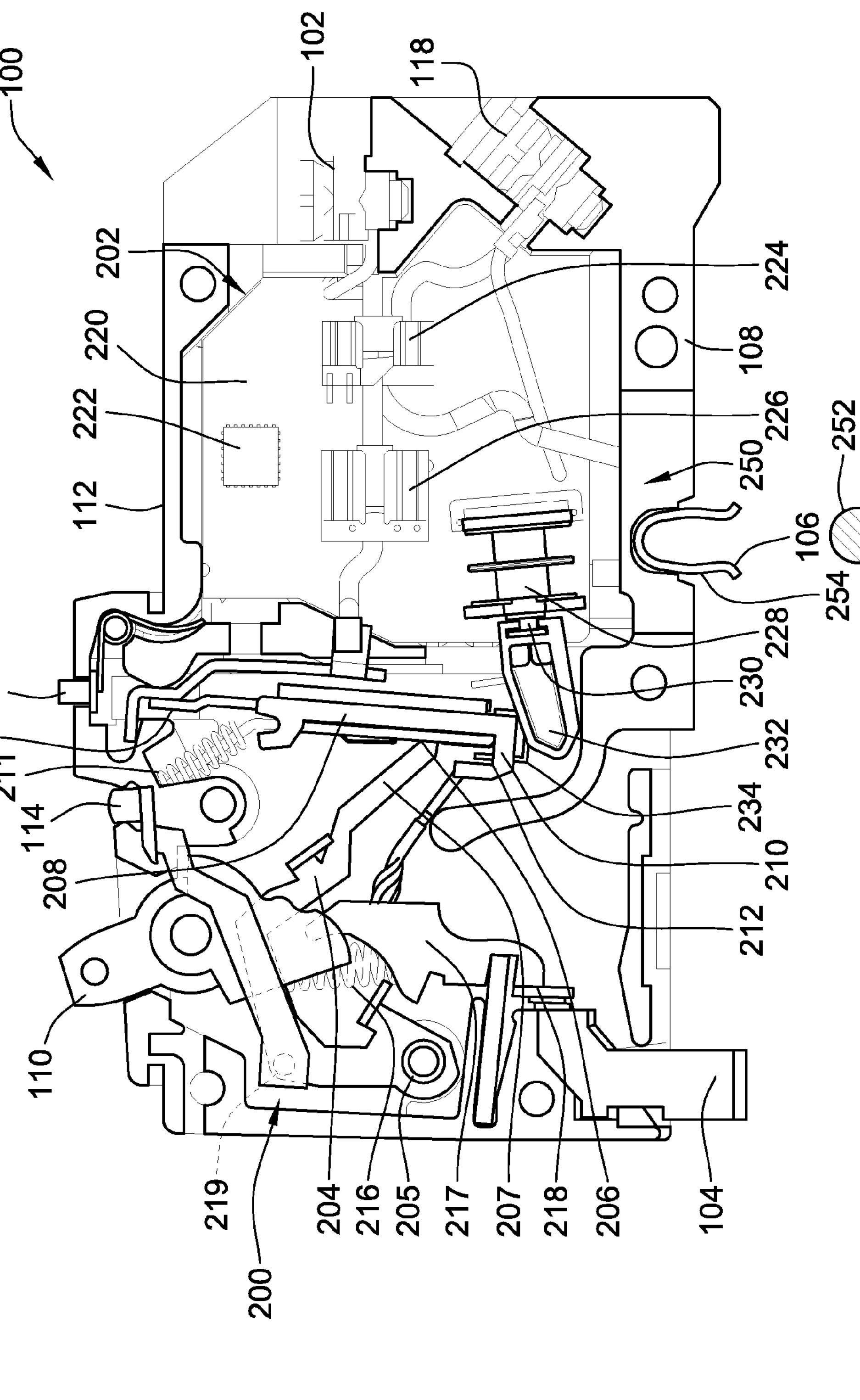
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FIG. 2A

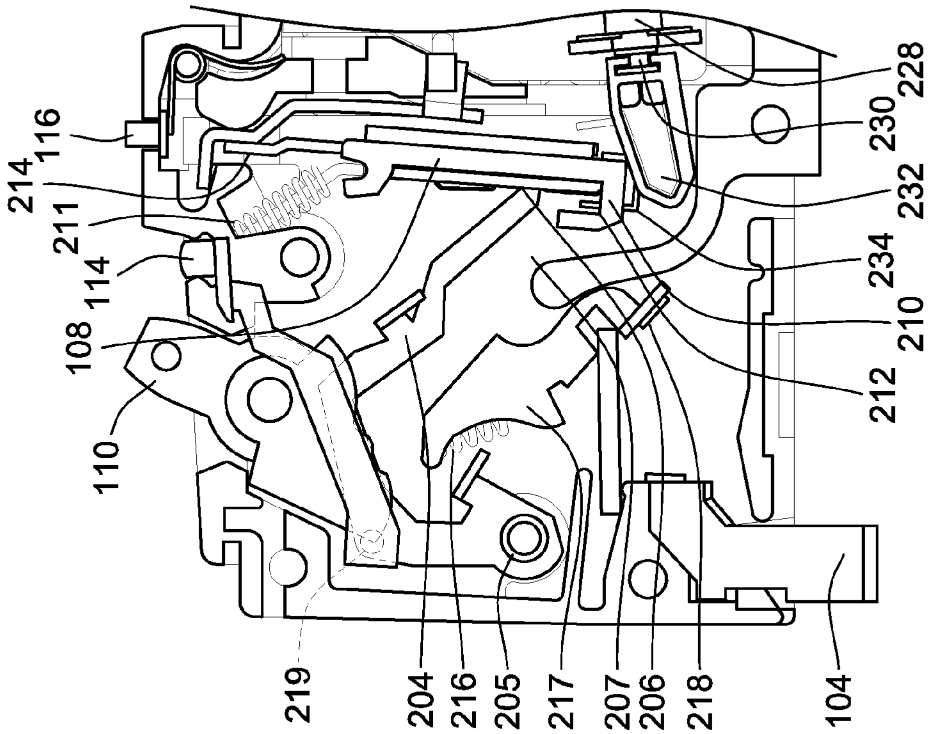
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FIG. 2C

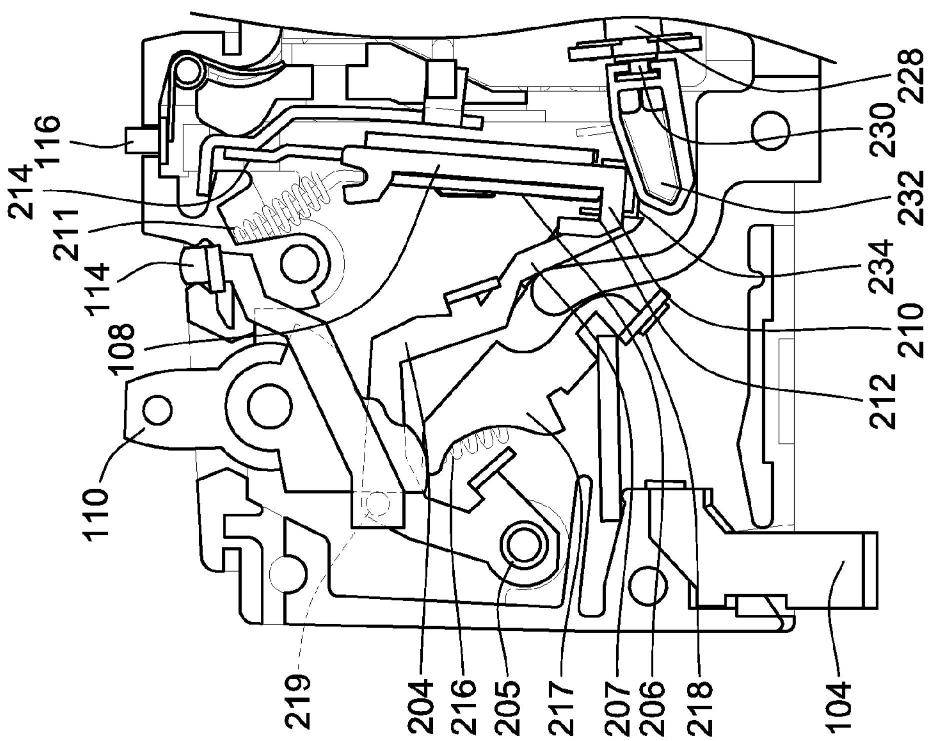
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FIG. 2B

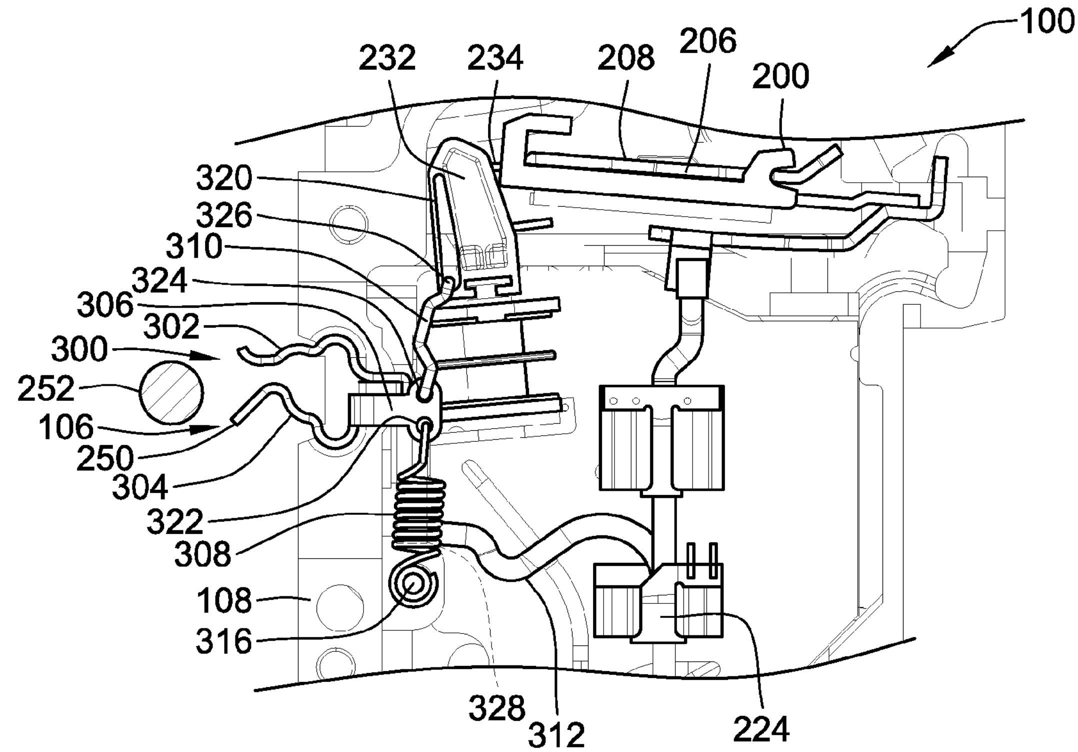
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FIG. 3A

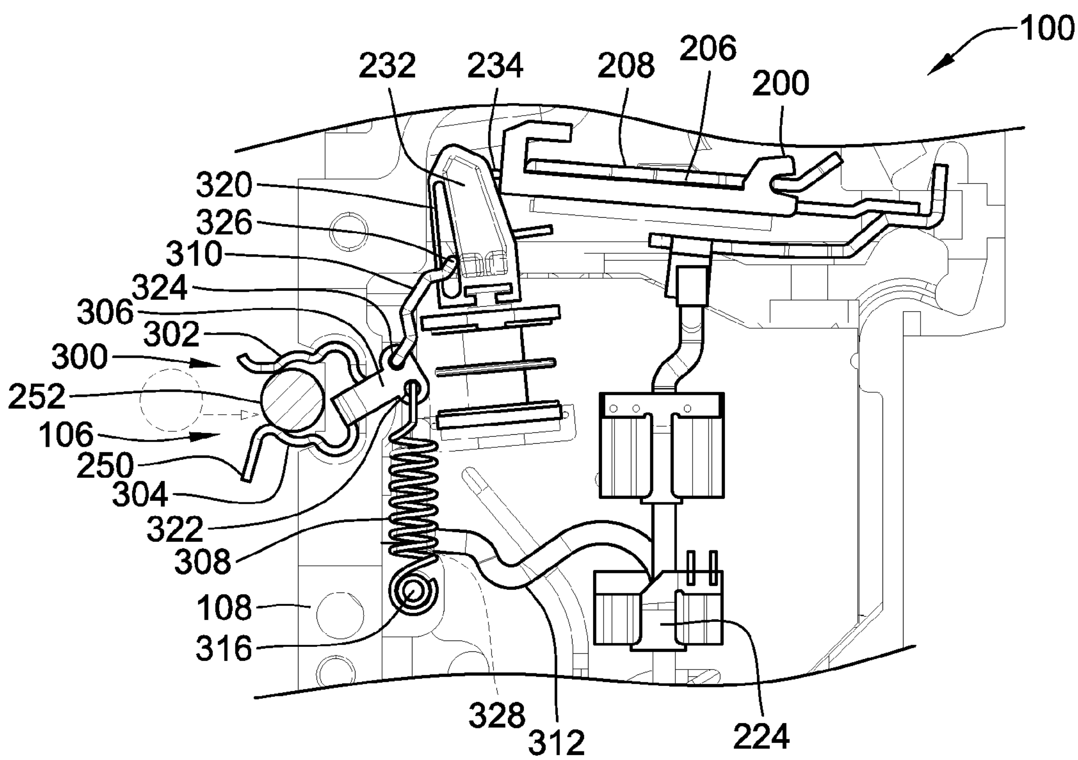
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FIG. 3B

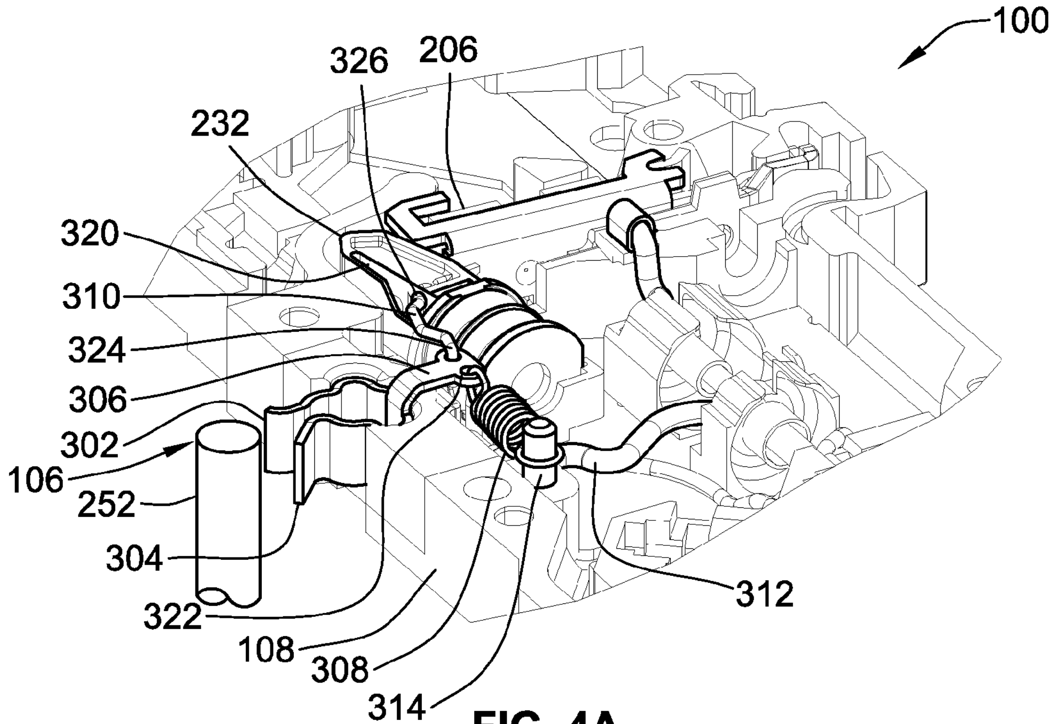

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FIG. 4A

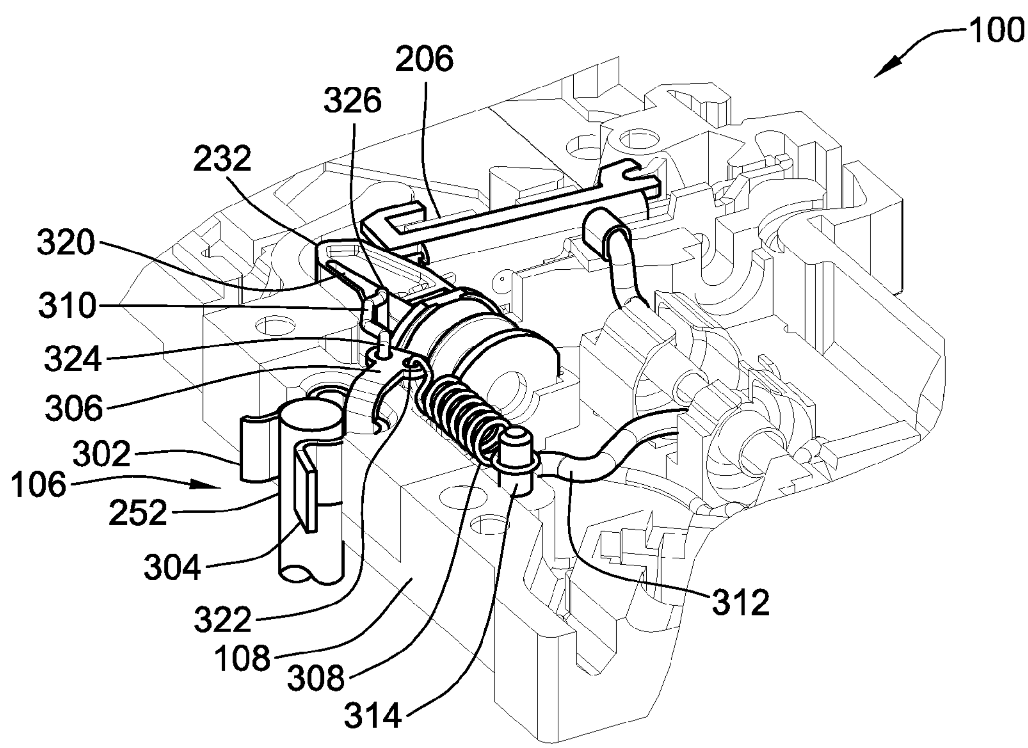

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FIG. 4B

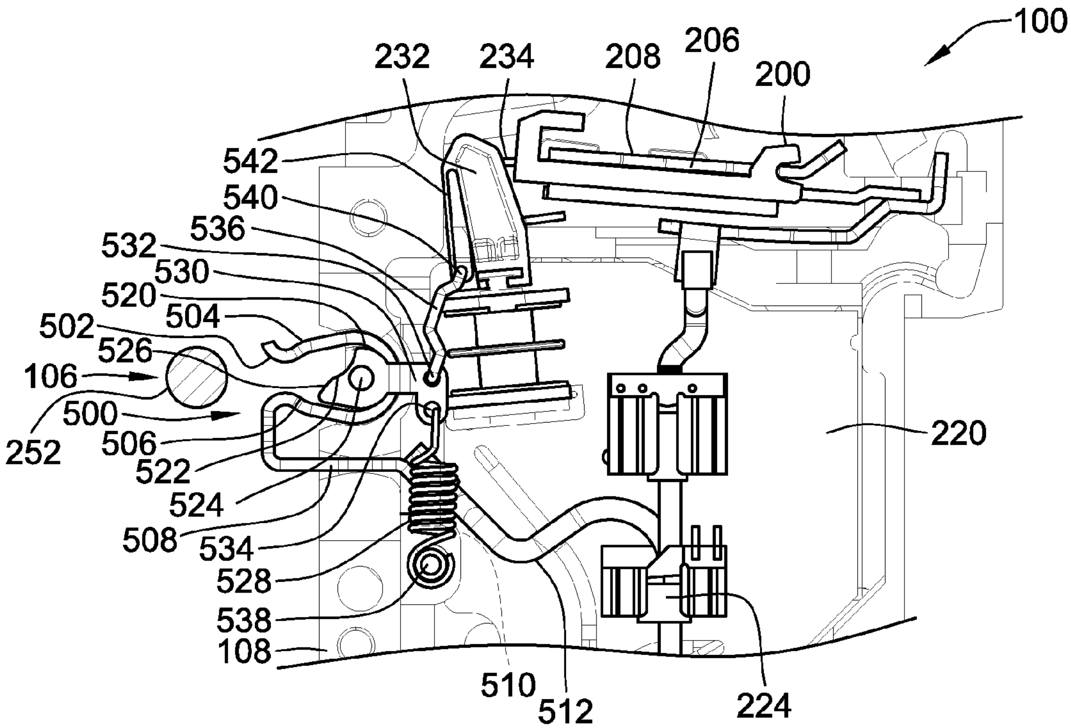
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FIG. 5A

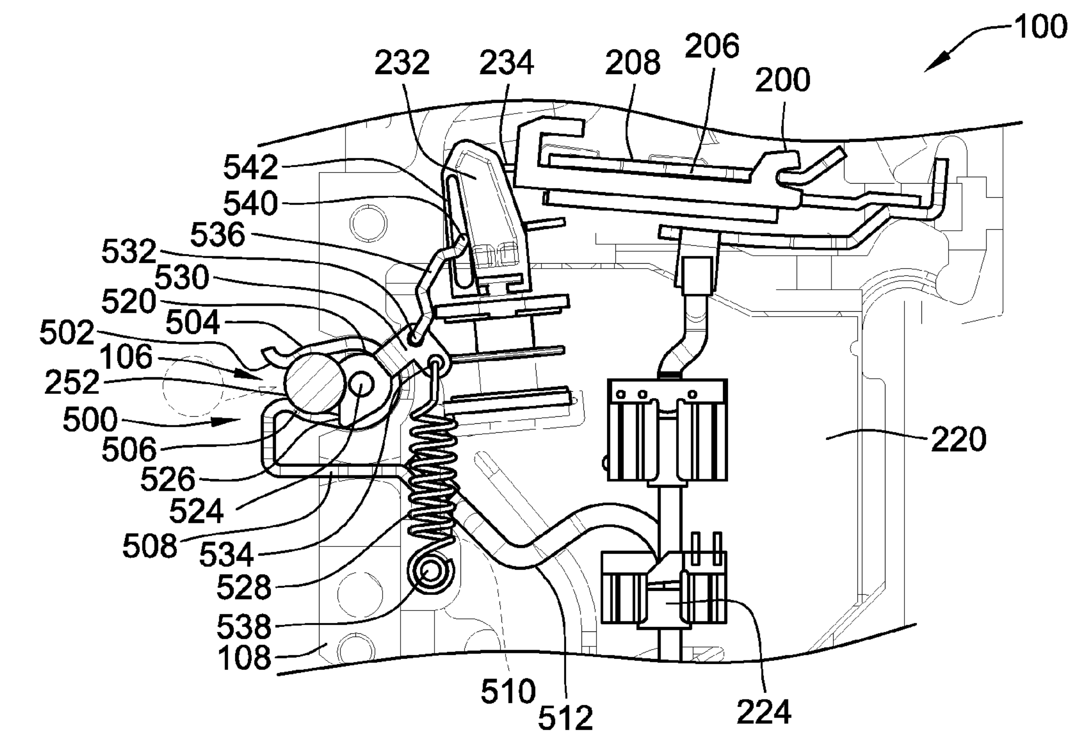
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FIG. 5B

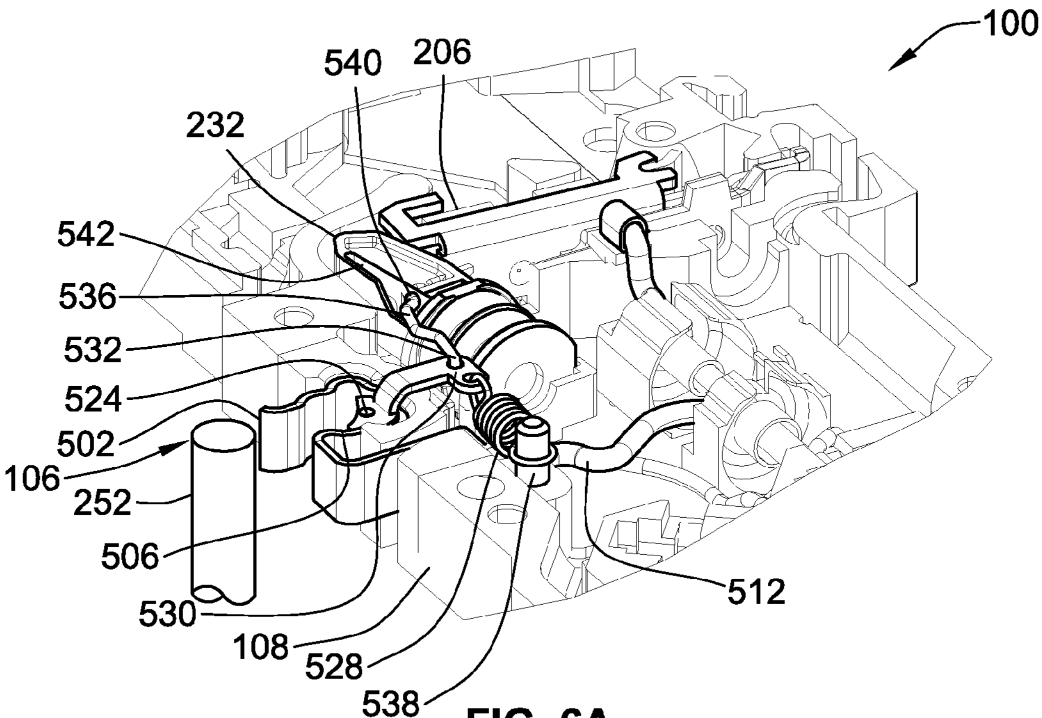
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FIG. 6A

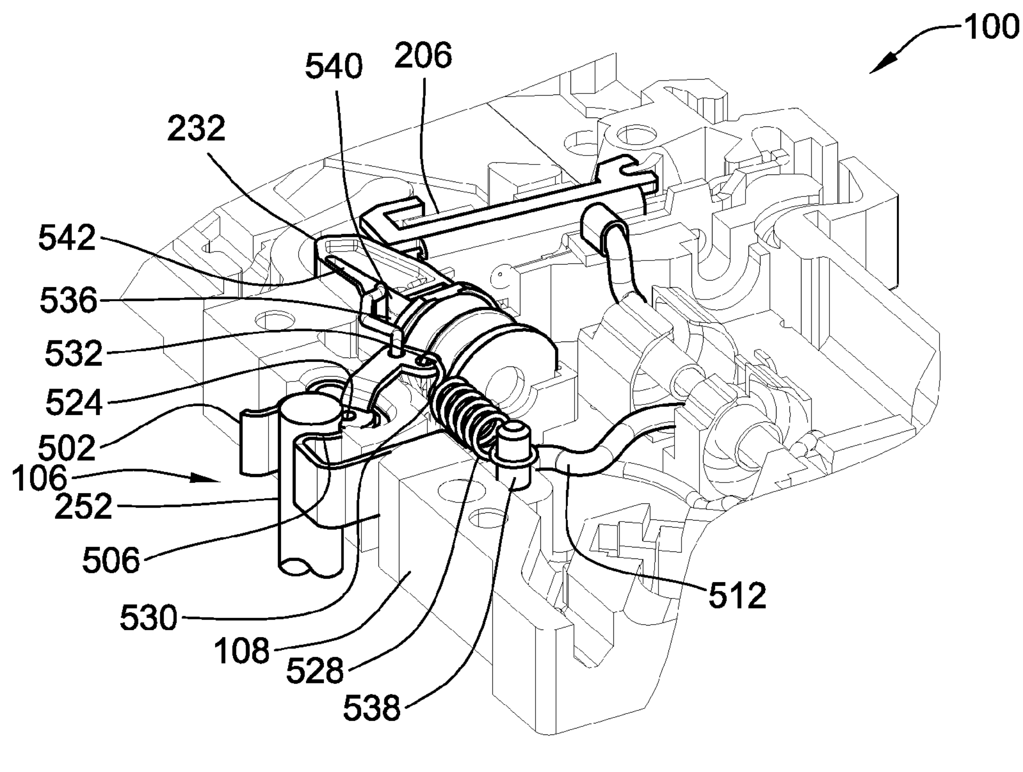
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FIG. 6B

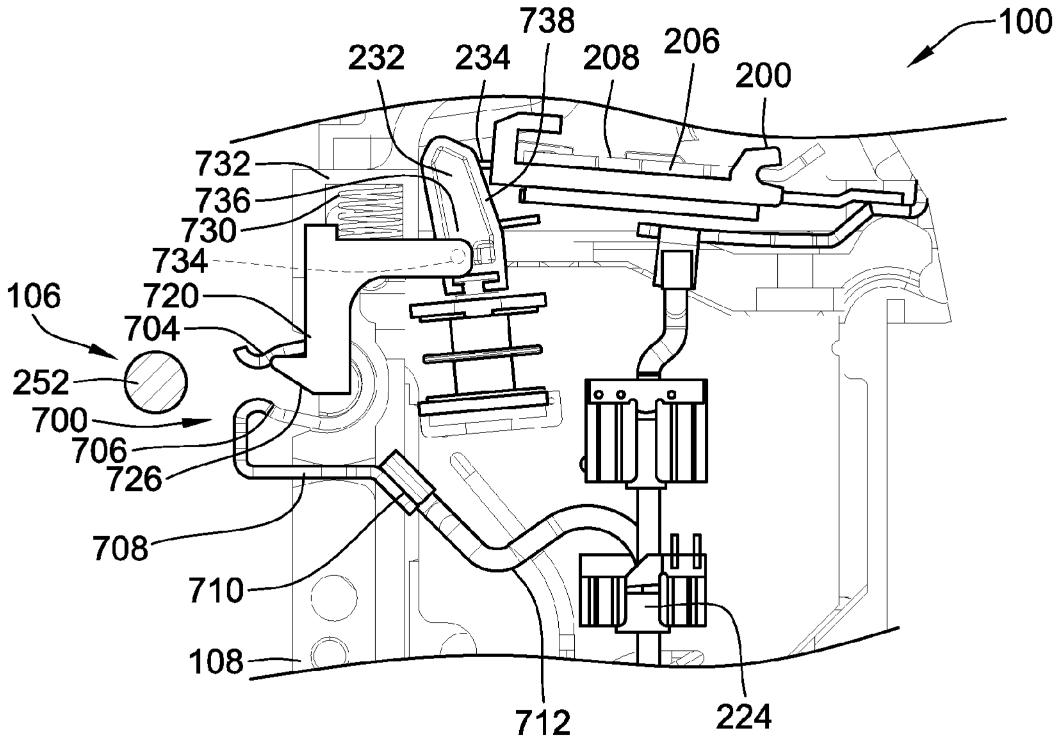
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FIG. 7A

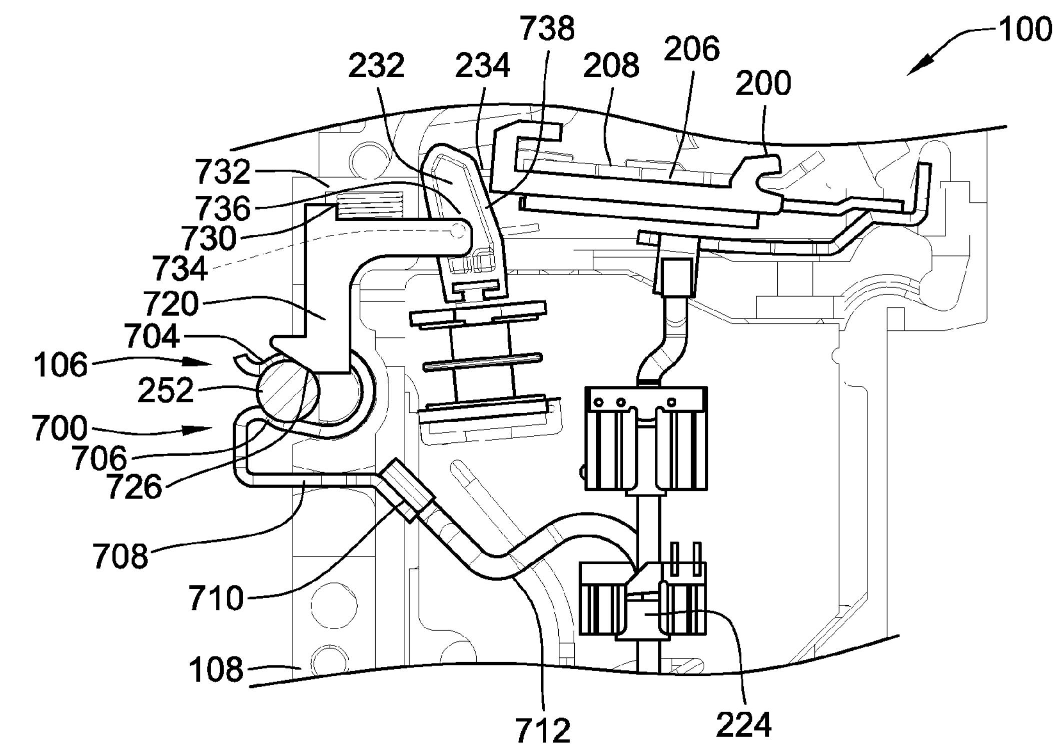
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FIG. 7B

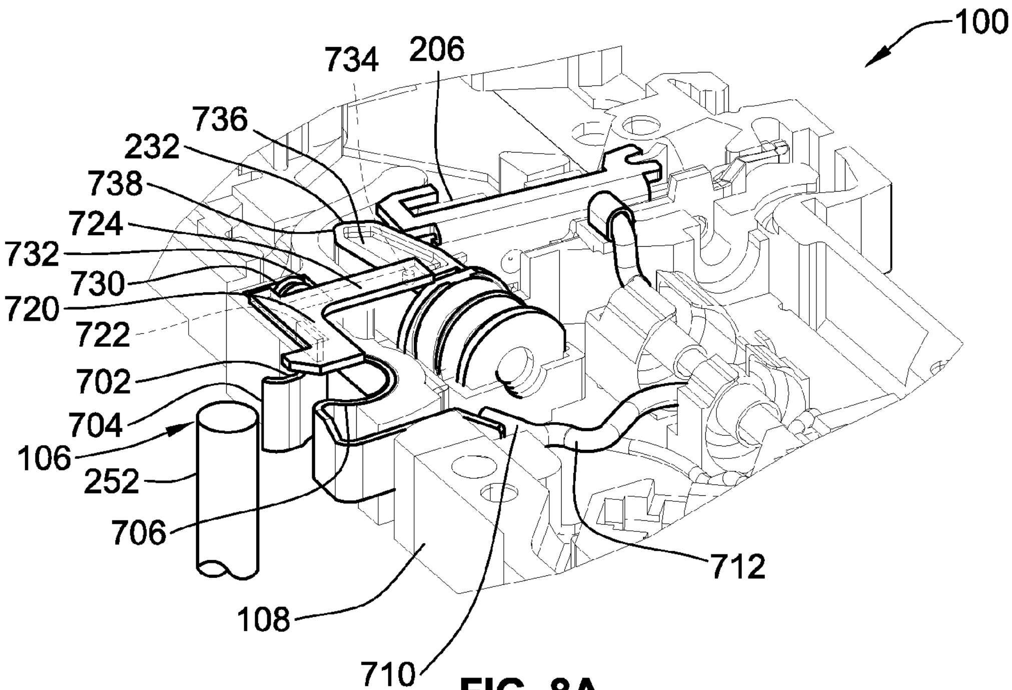
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FIG. 8A

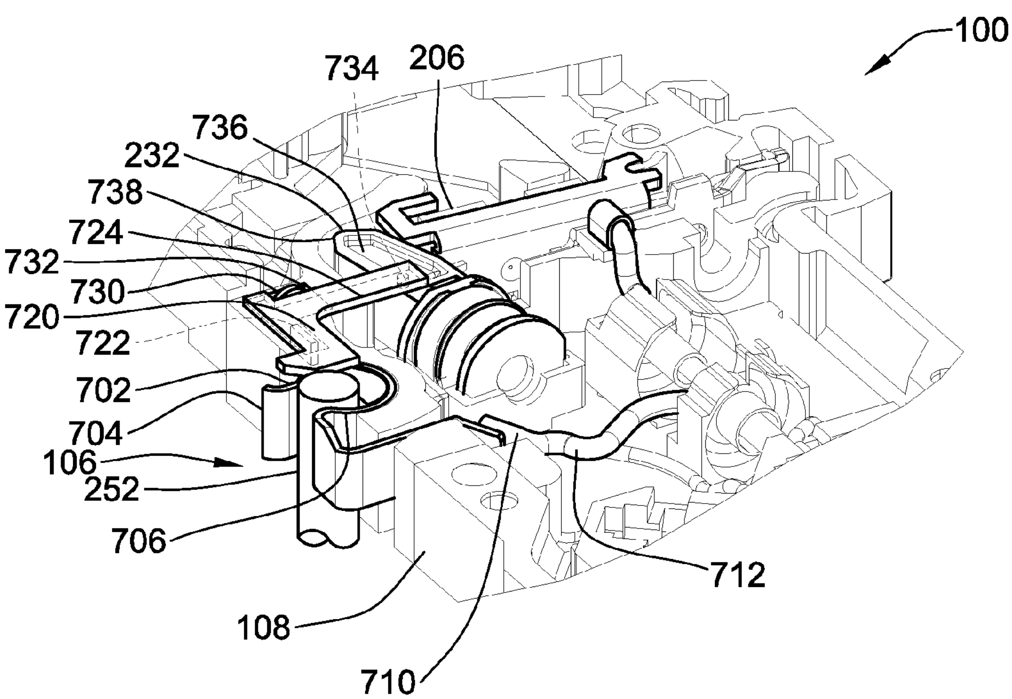
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FIG. 8B

CIRCUIT BREAKER WITH PLUG ON NEUTRAL CONNECTION LOCK-OUT MECHANISM

FIELD OF THE INVENTION

Aspects disclosed herein relate generally to circuit breakers, and, more particularly, to a circuit breaker having a lock-out mechanism to resetting the circuit breaker if an open neutral condition exists.

BACKGROUND

As is well-known, circuit breakers provide automatic power interruption to a monitored load when undesired fault conditions, such as an overload of current or a short circuit, occur. A circuit breaker is typically wired between a load and a power source on a line conductor. The load receives power from the line conductor from the circuit breaker and is directly connected to a ground conductor. A neutral rail or conductor is also connected to the power source through the circuit breaker to provide a return for the current back to the power source. A circuit breaker is an automatically operated electro-mechanical device designed to protect the load from damage when a fault occurs by breaking the connection on the line conductor to the load. A typical circuit breaker has a load connector and a line connector with a break mechanism interposed between the load connector (connected to the power input of a load device) and the line connector (connected to the power lead of a power source such as a panel board). Various fault conditions trip the circuit breaker thereby interrupting power flow between the load and the power source. A circuit breaker can be reset (either manually or automatically) to resume current flow to the load.

Circuit breakers have mechanical mechanisms that are tripped by overcurrents to interrupt power to a load. An overcurrent may be detected when the fault current generates sufficient heat in a bimetal strip causing the strip to bend. The mechanical deflection triggers a trip mechanism that includes a spring-biased trip lever to force a moveable contact attached to a moveable conductive blade away from a stationary contact, thereby breaking the circuit.

Other fault conditions may also include, for example, arc faults and ground faults which also require the interruption of the connection between the load and the power source. Such conditions require sensing electrical signals on the connection rather than a mechanical trigger. In order to provide protection against such faults, a circuit breaker may therefore also include electronic components that detect such fault conditions and cause the circuit breaker to electronically trip. The electronic components may be provided in addition to the thermal-magnetic tripping components. The electronic components process a signal output of a sensor that monitors current flowing in the circuit breaker to determine whether one of the fault conditions is present and to generate a fault signal and/or a trip signal. In response to the generation of a fault signal, a plunger is electrically activated trigger the trip mechanism and thereby interrupt power to the load.

The above mechanisms provide protection against fault conditions which occur from the line and neutral conductors that carry the power to the load. However, the neutral conductor also requires protection against accidental disconnection (open-neutral conditions) that will create a dangerous ungrounded open circuit for the load. For example, a potentially dangerous situation results from an open-neutral condition due to the panel board neutral connection of an electronic circuit breaker becoming unplugged while the line side connection between the circuit breaker and load remain connected. The situation is dangerous because in electronic circuit breakers, the electronics of the circuit breaker are sometimes powered between the line and neutral conductors (line-to-neutral powered) and will not function if the neutral connection between the circuit breaker and the panel in which the breaker is installed is lost. If the electronics of the circuit breaker are not powered, the circuit breaker will lose its advanced protection functions such as detection of ground faults or arc faults. Also, voltage may be supplied to loads which appear to be off and do not run because no current can flow, and because the neutral side of the circuit, which is normally near ground potential, is now near the potential level of the line power supply. In certain situations, there may be increased risk of losing this connection with a plug-on panel neutral connection which could be inadvertently disconnected if the circuit breaker is inadvertently bumped during service of an adjacent circuit breaker causing the panel board neutral connection to become unplugged.

Therefore there is a need for a circuit breaker that will be tripped when the neutral connection becomes unplugged. There is also a need for a mechanism that prevents the breaker from being switched to an on position if the neutral connection is not made to insure that the advanced electronics protection features are active.

BRIEF SUMMARY

A disclosed example is a circuit breaker with a neutral connector lockout mechanism. The circuit breaker has a trip mechanism that includes a handle which when in the on position, allows current flow between a load side connector and a line side connector. When tripped either mechanically via the heating of a metallic strip or electronically via the detection of a fault condition, a spring in the trip mechanism causes the handle to move to a tripped state thereby breaking the connections between the load side and line side connector. In order to reset the circuit breaker, the handle must be placed in an off position allowing the handle to be then moved to the on position and reestablishing the electrical connection between the load side connector and the line side connector. The circuit breaker includes a neutral connector that is connected to a neutral rail in a panel board and coupled to the power source. If the neutral connector is removed from the neutral rail, the circuit breaker will be tripped via a neutral lock-out mechanism. Without a neutral rail in the connector, the neutral lock-out mechanism prevents the circuit breaker from being reset to the on position. In such a manner, the circuit breaker protects against an open ground condition where the neutral rail is not connected and prevents the circuit breaker from being activated without the advanced electronics-driven tripping features from being used.

Three different neutral lock-out mechanisms are provided as examples. All three lock-out mechanisms use a trip link that when in a down position prevents the trip mechanism from being reset. The trip link also is moved to the down position when the neutral connector is removed from the neutral rail. A spring biases the lock-out mechanisms to move the trip link to the down position if the neutral connector is removed in all three mechanisms. The first mechanism links the lower jaw of a jaw type neutral connector to the spring. A rod connects the lower jaw with the trip link. The insertion of the neutral connector onto the neutral rail forces the lower jaw to rotate and pull the spring to a trigger position. The rotation of the lower jaw results in releasing the trip link allowing the trip mechanism to be reset.

A second example mechanism uses a rotating cam having an arm linked to the spring and a rod in contact with the trip link. When the neutral connector is removed from the neutral rail, the cam is rotated by the spring and the rod prevents the trip link from moving upward therefore preventing the trip mechanism from being reset. When the neutral connector is inserted onto the neutral rail, the neutral rail contacts the cam causing it to rotate and tensions the spring. The rod is moved upward allowing the trip link upward motion to reset the trip mechanism.

A third example mechanism uses a slider that has an arm in contact with the trip link. A compression spring forces the slider in a down position preventing the trip link from moving upward thereby preventing the trip mechanism from being reset. When the neutral connector is inserted onto the neutral rail, the slider is forced upward by the neutral rail thereby compressing the spring. The upward position of the slider allows the trip link to move upward permitting the resetting of the trip mechanism.

The foregoing and additional aspects of the present invention will be apparent to those of ordinary skill in the art in view of the detailed description of various embodiments, which is made with reference to the drawings, a brief description of which is provided next.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other advantages of the invention will become apparent upon reading the following detailed description and upon reference to the drawings.

FIG. **1**A is a perspective view of the front of a circuit breaker with a neutral connector locking mechanism;

FIG. **1**B is a perspective view of the back of the circuit breaker in FIG. **1**A;

FIG. **2**A is a cross section view of the internal components of the circuit breaker in FIG. **1**A with the handle in the on position;

FIG. **2**B is a cross section partial view of the internal components of the circuit breaker in FIG. **1**A with the handle in the tripped position;

FIG. **2**C is a cross section partial view of the internal components of the circuit breaker in FIG. **1**A with the handle in the off position for a reset;

FIG. **3**A is a cross section view of a first arrangement of the neutral connection mechanism in the locked position preventing the reset of the circuit breaker in FIGS. **1**A-**1**B;

FIG. **3**B is a cross section view of the arrangement in FIG. **3**A with a neutral connection mechanism connected to a neutral rail allowing the reset of the circuit breaker in FIGS. **1**A-**1**B;

FIG. **4**A is a perspective view of the first arrangement in FIG. **3**A in the locked position preventing the reset of the circuit breaker in FIGS. **1**A-**1**B;

FIG. **4**B is a perspective view of the first arrangement in FIG. **3**A with the neutral connection mechanism allowing the reset of the circuit breaker in FIGS. **1**A-**1**B;

FIG. **5**A is a cross section view of a second arrangement of the neutral connection mechanism in the locked position preventing the reset of the circuit breaker in FIGS. **1**A-**1**B;

FIG. **5**B is a cross section view of the second arrangement in FIG. **3**A with the neutral connection mechanism connected to a neutral rail allowing the reset of the circuit breaker in FIGS. **1**A-**1**B;

FIG. **6**A is a perspective view of the second arrangement in FIG. **5**A of the neutral connection mechanism in the locked position preventing the reset of the circuit breaker in FIGS. **1**A-**1**B;

FIG. **6**B is a perspective view of the second arrangement in FIG. **5**A with the neutral connection mechanism allowing the reset of the circuit breaker in FIGS. **1**A-**1**B

FIG. **7**A is a cross section view of a third arrangement of the neutral connection mechanism in the locked position preventing the reset of the circuit breaker in FIGS. **1**A-**1**B;

FIG. **7**B is a cross section view of the third arrangement in FIG. **7**A with the neutral connection mechanism connected to a neutral rail allowing the reset of the circuit breaker in FIGS. **1**A-**1**B;

FIG. **8**A is a perspective view of the third arrangement of the neutral connection mechanism in the locked position preventing the reset of the circuit breaker in FIGS. **1**A-**1**B; and

FIG. **8**B is a perspective view of the third arrangement in FIG. **7**A with the neutral connection mechanism connected to a neutral rail allowing the reset of the circuit breaker in FIGS. **1**A-**1**B.

While the invention is susceptible to various modifications and alternative forms, specific embodiments have been shown by way of example in the drawings and will be described in detail herein. It should be understood, however, that the invention is not intended to be limited to the particular forms disclosed. Rather, the invention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the invention as defined by the appended claims.

DETAILED DESCRIPTION

One disclosed example is a circuit breaker preventing electrical connection between a power line source and a load when a neutral rail is disconnected from the circuit breaker. The circuit breaker includes a line connector, a load connector and a neutral plug-on line connector. A trip mechanism has an on position allowing electrical connection between the line connector and the load connector, a tripped position interrupting electrical connection between the line connector and the load connector in response to detection of at least one fault condition, and an off position which is required before resetting the trip mechanism to the on position. A trip link is coupled to the trip mechanism, the trip link having a first position preventing the trip mechanism from being reset to the on position and a second position allowing the trip mechanism to be reset to the on position. A neutral lock mechanism is coupled to the neutral line connector. The neutral lock mechanism includes a spring that retains the trip link in the first position when the neutral rail is disconnected from the neutral plug-on line connector. The neutral lock mechanism actuates the spring when the neutral rail is connected to the neutral line connector allowing the trip link to move to the second position.

A circuit breaker prevents electrical connection between a power line source and a load when a neutral rail is disconnected from the circuit breaker. The circuit breaker includes a casing, a line connector affixed to one side of the casing, a load connector affixed to an opposite side of the casing and a neutral plug-on line connector having an upper jaw half and a lower jaw half allowing the neutral rail to be plugged on between the upper and lower jaws halves. A trip mechanism includes a handle. The trip mechanism has an on position allowing electrical connection between the line connector and the load connector and a tripped position interrupting electrical connection between the line connector and the load connector in response to detection of at least one fault condition. The trip mechanism also has an off position and the handle must be moved to the off position to reset the trip mechanism to the on position. A trip link is coupled to the trip mechanism. The trip link has a first position preventing the trip mechanism from being reset to the on position and a second position allowing the trip mechanism to be reset to the on position. A neutral lock mechanism is coupled to the neutral line connector. The neutral lock mechanism includes a spring coupled to the casing that retains the trip link in the first position when the neutral rail is unplugged from the neutral plug-on line connector. The neutral rail causes the neutral lock mechanism to actuate the spring when the neutral rail is connected between the jaw halves of to the neutral plug-on line connector allowing the trip link to move to the second position.

Turning now to FIGS. **1**A and **1**B, a perspective view of the front and back of a circuit breaker **100** is shown. The circuit breaker **100** includes a load side connector **102**, a power line connector **104**, a plug-on panel neutral line connector **106** and a casing **108**. The load side connector **102** is affixed to one side of the casing **108** and the power line connector **104** is affixed to the opposite side of the casing **108**. A handle **110** connected to a trip mechanism (detailed below) is mounted on a front panel **112**. The handle **110** may be placed in an on position (up position shown in FIG. **1**A) that causes the circuit breaker **100** to allow current flow between the power line connector **104** and the load side connector **102**. The handle **110** may be placed in a tripped condition cutting off current flow between the power line connector **104** and the load side connector **102**. A lens **114** is mounted below the handle **110** and shows an indication that the handle **110** is in a trip condition. A test button **116** is provided to test the internal electronics of the circuit breaker **100**. In this example, the circuit breaker **100** may be a miniature circuit breaker, such as the QO® and HOMELINE® family of circuit breakers available from Square D by Schneider Electric. However, it is to be understood that the principles discussed herein may be applied to other types of circuit breakers. A power line source such as a panel board is coupled to the circuit breaker **100** via connecting the line side connector **104** to the power line and a neutral line side rail to the plug-on panel neutral line connector **106**. A load may be connected to the circuit breaker by connecting the load side connector **102** to the power line to the load and a load neutral connector **118** to a neutral terminal on the load.

FIGS. **2**A-**2**C are cross section views of the internal components of the circuit breaker **100** in FIGS. **1**A-**1**B with the cover of the casing **108** removed. Like elements from FIG. **1**A-**1**B have like element numbers in FIGS. **2**A-**2**C. The circuit breaker **100** contains a trip mechanism **200** and an electronics module **202**. The trip mechanism **200** includes a trip lever **204** connected to the handle **110**. The trip lever **204** is roughly U-shaped having one end **205** that is in pivoting connection with the casing **108**. A latch **207** of the trip lever **204** is engaged with a slot in a latch seat **206** of an armature **208**. The armature **208** is in a calibrated position such that a free end **210** of the armature **208** contacts a yoke hook **212**. The armature **208** is biased in the calibrated position via a spring **211**. The yoke hook **212** may be triggered by a bi-metal strip **214** that bends when a heat threshold is exceeded by current flowing through the bi-metal strip **214**, thus causing the armature **208** to be released from the yoke hook **212** and releases the latch **207** from the latch seat **206**. A rotating contact arm **217** is rotatably coupled to the handle **110**. A spring **216** is coupled between the rotating contact arm **217** and the trip lever **204** and drives the trip lever **204** and handle **110** to the trip position (shown in FIGS. **1**A and **2**B). The movement of the trip lever **204** to the trip position breaks the electrical path between the power line connector **104** and the load power connector **102** by moving a contact **218** of the contact arm **217** away from the power line connector **104**.

As shown in FIG. **2**B, the handle **110** is in the tripped position. The trip lever **204** has rotated to a down position by force applied by the spring **216** because the latch **207** has been tripped and moved out of the latch seat **206**. The rotating contact arm **217** has also been moved by the spring **216** to a downward position separating the contact **218** from the power line connector **104**. As shown in FIG. **2**B, the handle **110** is in contact with a pin **219** which protrudes from the trip lever **204**.

In order to reset the handle **110** to the on position, the handle **110** is moved to the off position as shown in FIG. **2**C. The movement of the handle **110** tensions the spring **216** by rotating the trip lever **204** via pushing against the protruding pin **219**. The trip lever **204** is thus rotated so the latch **207** rests in the latch seat **206** of the armature **208**.

The handle **110** is then moved to the on position as shown in FIG. **2**A. In doing so, the contact arm **217** is rotated to bring the contact **218** to create an electrical contact with the power line connector **104**. In doing so, the contact arm **217** stretches the spring **216**. The trip lever **204** remains in the upward position because the latch **207** remains engaged in the latch seat **206** of the armature **208**.

The electronics module **202** includes a circuit board **220** that mounts a microprocessor **222**, a ground fault sensor **224**, a current sensor **226**, and a trip solenoid **228**. It is to be understood that the functions of the microprocessor **222** may be performed by a processor, microcontroller, controller, and/or one or more other suitable processing device(s) such as an application specific integrated circuit (ASIC), a programmable logic device (PLD), a field programmable logic device (FPLD), a field programmable gate array (FPGA), discrete logic, etc.

The microprocessor **222** may electronically cause the circuit breaker **100** to trip based on signals sensed by the ground fault sensor **224** or the current sensor **226** from the current flowing between the load connector **102** and the line connector **104**. On detection of a fault condition, the microprocessor **222** sends a signal to a trip circuit that causes the trip solenoid **228** to activate a plunger **230** to pull a connected trip link **232** down. The trip link **232** includes a clamp **234** that is in contact with the armature **208**. When the trip link **232** is motivated by the plunger **230** being activated by the solenoid **228**, it moves downward pushing the clamp **234** thus causing the armature **208** to move downward to release the latch **207** causing the spring **216** to drive the trip lever **204** and handle **110** to the trip position thus breaking the electrical path between the line connector **104** and the load connector **102**. The microprocessor **222** analyzes the signals from the sensors **224** and **226** for indicators of fault conditions that may include, but are not limited to ground faults, arcing faults, overloads, and short-circuits. When the microprocessor **222** determines a safe condition, it deactivates the solenoid **228** releasing the plunger **230** and pushing the trip link **232** and the clamp **234** upwards. This allows the armature **208** to be tensioned in the set position to hold the latch **207** of the trip lever **204** as shown in FIG. **2**A

The microprocessor **222** monitors the inputs from several input circuits mounted on the circuit board **220** including a zero crossing circuit and voltage monitoring circuit, a differential current sensor circuit, an integrator circuit, a high frequency detection circuit, a push to test circuit, and a temperature sensor circuit. In this example, the differential current sensor circuit is coupled to the ground fault sensor **224**. The ground fault sensor **224** and differential current sensor circuit provide an input to the microprocessor **222** indicating the presence of a ground fault or arcing ground fault from the load connector **102**. The current sensor **226** and the integrator circuit provide an input to the microprocessor **222** indicating the presence of an arc fault on the load connector **102**.

A neutral locking mechanism **250** is coupled to a neutral line rail **252** which is coupled to a neutral terminal of the power line source such as a panel board (not shown). The neutral locking mechanism **250** prevents the resetting of the circuit breaker **100** if the neutral line rail **252** is not connected to the plug-on neutral line connector **106**. The neutral locking mechanism **250** also trips the circuit breaker **100** if the neutral rail **252** is disconnected from the plug-on neutral line connector **106**. Three separate arrangements for the locking mechanism **250** are disclosed that work in conjunction with the circuit breaker **100**. In each of arrangements for the neutral locking mechanism **250**, the plug-on neutral line connector **106** includes a jaw coupler **254** that clamps onto the neutral rail **252**.

Each of the mechanisms described below uses a tension or compression spring to bias the lock-out mechanism to a position that holds the trip mechanism **200** shown in FIG. **2**A in the tripped position shown in FIG. **2**B preventing a reset of the circuit breaker **100**. Each of the embodiments has a mechanical member which contacts the neutral rail **252** in the jaw coupler **254** in such a way that as when the neutral rail **252** is connected to the neutral connector **106** of the circuit breaker **100**, the lock-out mechanism is displaced, overcoming the spring bias from the tension spring, and actuates the lock-out mechanism to a position that frees the restraint on the trip mechanism **200** allowing the handle **110** to be reset to the on position. After the trip mechanism **200** is freed, the circuit breaker **100** can then be reset by moving handle **110** to the off position shown in FIG. **2**C and then the handle **110** may be moved to the on position as shown in FIG. **2**A. Likewise if the circuit breaker **100** is installed between the load and the power line source, but the panel neutral rail **252** is disconnected or unplugged from the jaw coupler **254** of the neutral line connector **106** while the circuit breaker **100** is in either the on or off position in FIG. **2**A or **2**C, the spring in the lock-out mechanism **250** will cause the trip mechanism **200** to be moved to the tripped position in FIG. **2**B therefore interrupting power between the power source and the load.

FIGS. **3**A-**3**B are cross section views and FIGS. **4**A-**4**B are perspective views of a first arrangement **300** which may constitute the neutral locking mechanism **250** for the circuit breaker **100** shown in FIGS. **1**A-**1**B and FIGS. **2**A-**2**C. Like element numbers in FIGS. **1** and **2** are designated with the same element numbers in FIGS. **3** and **4**. FIGS. **3**A and **4**A show the arrangement **300** in the locked position that prevents the trip mechanism **200** from being reset to the on position shown in FIG. **2**A. FIGS. **3**B and **4**B show the arrangement **300** where the neutral conductor rail **252** is connected in the neutral line conductor **106** and therefore allows the trip mechanism **200** to be reset to the on position as shown in FIG. **2**A.

In the arrangement **300** shown in FIGS. **3**-**4**, the jaw coupler **254** includes a fixed upper jaw half **302** and a rotating lower jaw half **304**. The rotating lower jaw half **304** is coupled to a pivoting actuating arm **306**. The pivoting actuating arm **306** is coupled to a tensioning spring **308** that biases the rotating lower jaw half **304** to the position shown in FIG. **3**A to pull a rod **310** to hold the trip link **232** in a downward position thus preventing the trip mechanism **200** from being reset to the on position as shown in FIG. **2**A. A neutral wire **312** is coupled through the ground fault sensor **224** and is connected to the circuit board **220** in FIGS. **2**A and **2**B. FIGS. **3**B and **4**B shows the neutral line rail **252** which is connected to the jaw coupler **254**.

The upper jaw half **302** is preferably made of a conductive metal such as copper alloy while the lower jaw half **304** is preferably made of steel to handle higher stress. The upper jaw half **302** is the primary conductor path for the neutral connection, as well as supporting the clamp load. The lower jaw half **304** transfers the energy from the tension spring **308** to create the clamp on the neutral rail **252**. The lower jaw half **304** also actuates the lockout mechanism **250**. In this example the lock mechanism **250** includes a slot **320** in the trip link **232**. The lower jaw half **304** is coupled to the actuating arm **306** which contacts the trip link **232** via the rod **310**. The tension spring **308** creates the mechanical force to actuate the neutral locking mechanism **250**. One end of the spring **308** is attached to a post **314** in the casing **108** of the circuit breaker **100**. The other end of the spring **308** is hooked into a hole **322** of the actuating arm **306**. Another hole **324** on the actuating arm **306** holds a hooked shaped end of the rod **310**. The opposite end of the rod **310** includes an arm **326** that extends into the slot **320** in the trip link **232**. The neutral wire **312** is soldered to a clip **328** that provides electrical connection to the jaw coupler **254**.

As shown in FIGS. **3**A and **4**A, the lock mechanism arrangement **300** locks the armature **208** in the tripped (lower) position when the neutral rail **252** is not held by the upper and lower jaw halves **302** and **304**. The armature **208** in the lower position prevents the latch **207** from being engaged with the latch seat **206** and therefore the handle **110** cannot be moved to on position shown in FIG. **2**A. Without the neutral rail **252**, the actuating arm **306** is pulled in a clockwise direction by the tension spring **308** and thereby the arm **326** of the rod **310** sits in the bottom of the slot **320** and therefore prevents the trip link **232** from moving upward. Since the trip link **232** restricts the movement of the clamp **234** which is in turn coupled to the armature **208**, the armature **208** is prevented from moving upward as well.

When the neutral rail **252** is inserted in the jaw coupler **254** as shown in FIGS. **3**B and **4**B, the rail **252** pushes the lower jaw half **304** down thereby rotating the actuating arm **306** in a counterclockwise direction. The actuating arm **306** therefore stretches the tension spring **308** by the rotational motion. The actuating arm **306** also moves the rod **310** up so the arm **318** travels upwards in the slot **320** of the trip link **232**. The lock mechanism arrangement **300** therefore allows the trip link **232** to be moved upward to allow the armature **208** to be tensioned upward allowing the latch **207** to be reset to the on position. If the neutral rail **252** is removed, the tension spring **308** pulls the pivoting actuating arm **306** in a clockwise direction thus causing the rod **310** to pull the arm **318** down in the slot **320** and moving the trip link **232** down. The trip link **232** moves the clamp **234** downward causing the armature **208** to move downward releasing the latch **207** of the trip lever **204** and causing the trip mechanism **200** to be triggered to the trip position shown in FIG. **2**B.

FIGS. **5**A and **5**B are cross section views of and FIGS. **6**A-**6**B are perspective views of a second arrangement **500** that constitute the neutral lock out mechanism **250** in FIGS. **2**A-**2**C. Like element numbers in FIGS. **1** and **2** are designated with the same element numbers in FIGS. **5** and **6**. The second arrangement **500** is similar to the first arrangement **300** in FIGS. **3**-**4**. The second mechanism **500** includes an integrated neutral jaw/clip **502**. The neutral jaw/clip **502** has an upper jaw half **504** and a lower jaw half **506** that clamp a neutral line rail such as the neutral line rail **252** in FIGS. **5**B and **6**B in electrical connection to the circuit breaker **100**. The lower jaw **506** is coupled to a tab **508** that creates an electrical connection via a clamp **510** to a neutral wire **512** that in turn is coupled through the current sensor **224** to the circuit board **220**.

A pivoting cam **520** rotates independently of the jaw halves **504** and **506**. The pivoting cam **520** includes a hole **522** that rotates around a pin **524** on the casing **108** of the circuit breaker **100**. The cam **520** includes a chamfer **526** that is biased by a tension spring **528**. The chamfer **526** is pushed downward (counter clockwise) by the insertion of the neutral rail **252** as shown in FIGS. **5**B and **6**B. The cam **520** further includes an arm **530** having a hole **532** for the insertion of one end of the tension spring **528** and another hole **534** for the insertion of a hooked end of a rod **536**. The opposite end of the tension spring **528** is hooked into a post **538** formed in the casing **108**. The opposite end of the rod **536** includes an arm **540** that is engaged in a slot **542** in the trip link **232**.

As shown in FIGS. **5**A and **6**A, the lock out mechanism arrangement **500** locks the armature **208** in the tripped (lower) position when the neutral rail **252** is not held by the upper and lower jaw halves **504** and **506**. The armature **208** in the lower position prevents the latch **207** from being engaged with the latch seat **206** and therefore the handle **110** cannot be moved to the on position shown in FIG. **2**A. The cam **520** is pulled in a clockwise direction by the tension spring **528** thereby causing the arm **540** of the rod **536** to sit in the bottom of the slot **542** and therefore prevents the trip link **232** from moving upward as shown in FIGS. **5**A and **6**A. Since the trip link **232** restricts the upward movement of the clamp **234** which is in turn coupled to the armature **208**, the armature **208** is prevented from moving upward and holding the latch **207** of the trip lever **204**.

When the neutral line rail **252** is inserted in the jaw connector **502** as shown in FIGS. **5**B and **6**B, the neutral line rail **252** pushes the chamfer **526** down thereby rotating the cam **520** and arm **530** in a counterclockwise direction. The arm **530** therefore causes tensioning of the tension spring **528**. The arm **530** also moves the rod **536** up so the arm **540** travels upwards in the slot **542** of the trip link **232**. The lock out mechanism arrangement **500** therefore allows the trip link **232** to be moved upward in the position shown in FIGS. **5**B and **6**B. This allows the clamp **234** to move upward and therefore allows the armature **208** to be tensioned upward allowing the latch **207** to be reset to the on position. If the neutral rail **252** is removed, the spring **528** pulls the cam **520** in a clockwise direction thus causing the rod **536** to pull the arm **540** down in the slot **542** and moving the trip link **232** down. The trip link **232** causes the clamp **234** to move downward and thereby causes the armature **208** to move downward releasing the latch **207** of the trip lever **204** and causing the trip mechanism **200** to be triggered to the trip position shown in FIG. **2**B.

The neutral jaw/clip **502** mechanically fastens the circuit breaker **100** to the neutral rail **252** and provides the electrical connection to the neutral rail from the power source. The pivoting cam **520** actuates the mechanism **500**. The chamfer surface **526** causes the cam **520** to rotate when it contacts the neutral line rail **252** and provides a connection point for the rod **536** and tension spring **528** as described above. The cam **520** of the arrangement **500** allows some rotational freedom of the neutral jaw/clip **502** to maintain ease of installation of the circuit breaker **100** to a load, and at the same time positions the neutral jaw/clip **502** so it will not interfere with the operation of the parts of the lock-out mechanism such as the cam **520**.

FIGS. **7**A and **7**B are cross section views of and FIGS. **8**A-**8**B are perspective views of a third arrangement **700** that may constitute the neutral lock out mechanism **250** in FIGS. **2**A-**2**C. Like element numbers in FIGS. **1** and **2** are designated with the same element numbers in FIGS. **7** and **8**. The third arrangement **700** includes an integrated jaw coupler **702**. The jaw coupler **702** as shown in FIGS. **8**A and **8**B has an upper jaw **704** and a lower jaw **706** that clamp a neutral line rail such as the neutral line rail **252** in FIGS. **7**B and **8**B to create an electrical connection to the circuit breaker **100**. The lower jaw **706** is coupled to a tab **708** that creates an electrical connection via a clamp **710** to a neutral wire **712** that in turn is coupled through the current sensor **224** to the circuit board **220**.

A slider **720** translates on a track (not shown) in the casing **108** of the circuit breaker **100** between an up and down position. The slider **720** includes an actuation arm **722** and a perpendicular spring arm **724**. The actuation arm **722** has a sloped contact surface **726** that sits between the upper and lower jaws **704** and **706**. The spring arm **724** is in contact with a compression spring **730** that rests in a recess **732** formed by the casing **108**. The end of the spring arm **724** has a protruding pin **734**. The pin **734** rests within a recess **736** formed by a border edge **738** of the trip link **232**.

As shown in FIGS. **7**A and **8**A, the lock mechanism arrangement **700** locks the armature **208** in the tripped (lower) position when the neutral rail **252** is not held by the upper and lower jaw halves **704** and **706** of the integrated jaw coupler **702**. The armature **208** in the lower position prevents the latch **207** from being engaged and therefore the handle **110** cannot be moved to the on position shown in FIG. **2**A. The spring **730** pushes the slider **720** down thereby causing the pin **734** to sit in the bottom of the recess **736** and against the border **738** of the trip link **232**. This prevents the trip link **232** from moving upward as shown in FIGS. **7**A and **8**A. Since the trip link **232** restricts the upward movement of the clamp **234** which is in turn coupled to the armature **208**, the armature **208** is prevented from moving upward as well.

When the neutral rail **252** is clamped in the jaw connector **702** as shown in FIGS. **7**B and **8**B, the neutral line rail **252** pushes against the contact surface **726** thereby forcing the slider **720** to move upwards and compress the spring **730**. The arm **724** also moves the pin **734** up so the trip link **232** may be moved upward in the position shown in FIGS. **7**B and **8**B. This allows the clamp **234** to move upward and therefore allows the armature **208** to be tensioned upward allowing the latch **207** to be reset to the on position. If the neutral rail **252** is removed, the spring **730** pushes the slider **720** downward causing the pin **734** to push against the border **738** and pull the trip link **232** down. The trip link **232** causes the clamp **234** to move downward and thereby causes the armature **208** to move downward releasing the latch **207** of the trip lever **204** and causing the trip mechanism **200** to be triggered to trip the position shown in FIG. **2**B.

While particular embodiments and applications of the present invention have been illustrated and described, it is to be understood that the invention is not limited to the precise construction and compositions disclosed herein and that various modifications, changes, and variations can be apparent from the foregoing descriptions without departing from the spirit and scope of the invention as defined in the appended claims.

What is claimed is:

1. A circuit breaker preventing electrical connection between a power line source and a load when a neutral rail is disconnected from the circuit breaker, the circuit breaker comprising:

a line connector;

a load connector;

a neutral plug-on line connector;

a trip mechanism having an on position allowing electrical connection between the line connector and the load connector, a tripped position interrupting electrical connection between the line connector and the load connector in response to detection of at least one fault condition, and an off position which is required before resetting the trip mechanism to the on position;

a trip link coupled to the trip mechanism, the trip link having a first position preventing the trip mechanism from being reset to the on position and a second position allowing the trip mechanism to be reset to the on position; and

a neutral lock mechanism coupled to the neutral plug-on line connector, the neutral lock mechanism including a spring that retains the trip link in the first position when the neutral rail is disconnected from the neutral plug-on line connector, the neutral lock mechanism actuating the spring when the neutral rail is connected to the neutral plug-on line connector allowing the trip link to move to the second position.

2. The circuit breaker of claim **1**, wherein the neutral lock mechanism includes an upper jaw half and a rotating lower jaw half, the lower jaw half including a pivoting actuating arm coupled to the spring and a rod in contact with the trip link.

3. The circuit breaker of claim **1**, wherein the neutral lock mechanism includes a cam having an arm coupled to the spring and a rod in contact with the trip link, the cam rotating between a first position holding the rod down, and a second position on insertion of the neutral rail moving the rod upward allowing the trip link to move to the second position.

4. The circuit breaker of claim **3**, wherein the neutral lock mechanism further includes an upper jaw half and a lower jaw half, the cam rotating independently of the upper and lower jaw halves.

5. The circuit breaker of claim **1**, wherein the neutral lock mechanism includes a slider having an actuating arm and a perpendicular spring arm in contact with the spring and the trip link, the slider having a first position wherein the perpendicular spring arm holds the trip link in the first position and a second position compressing the spring and allowing the trip link to move to the second position.

6. The circuit breaker of claim **1**, further comprising:

a sensor electrically coupled to the line connector;

a microcontroller coupled to the sensor that receives power derived from a line current that passes through the circuit breaker when the circuit breaker is in the on state, the microcontroller detecting a fault condition and sending a trip signal; and

a trip solenoid coupled to the trip link that causes the trip mechanism to trip the circuit breaker in response to receiving a trip signal from the microcontroller.

7. The circuit breaker of claim **6**, wherein the fault conditions include a ground fault and an arc fault.

8. The circuit breaker of claim **1**, wherein the trip link includes a slot that engages part of the neutral lock mechanism.

9. The circuit breaker of claim **1**, wherein the trip link includes a recess that engages part of the neutral lock mechanism.

10. A circuit breaker preventing electrical connection between a power line source and a load when a neutral rail is disconnected from the circuit breaker, the circuit breaker comprising:

a casing;

a line connector affixed to one side of the casing;

a load connector affixed to an opposite side of the casing;

a neutral plug-on line connector having an upper jaw half and a lower jaw half allowing the neutral rail to be plugged on between the upper and lower jaws halves;

a trip mechanism including a handle, the trip mechanism having an on position allowing electrical connection between the line connector and the load connector, a tripped position interrupting electrical connection between the line connector and the load connector in response to detection of at least one fault condition, and an off position, wherein the handle must be moved to the off position to reset the trip mechanism to the on position;

a trip link coupled to the trip mechanism, the trip link having a first position preventing the trip mechanism from being reset to the on position and a second position allowing the trip mechanism to be reset to the on position; and

a neutral lock mechanism coupled to the neutral plug-on line connector, the neutral lock mechanism including a spring coupled to the casing that retains the trip link in the first position when the neutral rail is unplugged from the neutral plug-on line connector, the neutral rail causing the neutral lock mechanism to actuate the spring when the neutral rail is connected between the jaw halves of to the neutral plug-on line connector allowing the trip link to move to the second position.

11. The circuit breaker of claim **10**, wherein the lower jaw half rotates on a pivot point on the casing, and wherein the neutral lock mechanism includes a pivoting actuating arm connected to the lower jaw half, the arm including one end coupled to the spring and coupled to a rod in contact with the trip link.

12. The circuit breaker of claim **10**, wherein the neutral lock mechanism includes a cam having an actuating arm having one end coupled to the spring and a rod in contact with the trip link, the cam rotating between a first position holding the rod down, and a second position on connection of the neutral rail between the two jaw halves moving the rod upward allowing the trip link to move to the second position.

13. The circuit breaker of claim **12**, wherein the cam rotates independently of the upper and lower jaw halves.

14. The circuit breaker of claim **10**, wherein the neutral lock mechanism includes a slider having an actuating arm and a perpendicular spring arm in contact with the spring and the trip link, wherein the spring is located in a recess in the casing, the slider having a first position wherein the perpendicular spring arm holds the trip link in the first position and a second position compressing the spring and allowing the trip link to move to the second position.

15. The circuit breaker of claim **10**, further comprising:

a sensor electrically coupled to the line connector;

a microcontroller coupled to the sensor that receives power derived from a line current that passes through the circuit breaker when the circuit breaker is in the on state, the microcontroller detecting a fault condition and sending a trip signal; and

a trip solenoid coupled to the trip link that causes the trip mechanism to trip the circuit breaker in response to receiving a trip signal from the microcontroller.

16. The circuit breaker of claim **15**, wherein the fault conditions include a ground fault and an arc fault.

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